DISTRIBUTION OF CALANOID COPEPODS

IN THE GULF OF MEXICO

by

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Spatial distribution of calanoid copepods in the Gulf of Mexico has been estimated mainly on the basis of collections by the Bureau of Commercial Fisheries research vessel ALASKA. Operations extended from 1951 to 1953 in Gulf waters offshore of the 10 fathom isobath. Collecting stations are depicted on the first slide.

The samples, originally collected as part of a general survey are best suited for qualitative examination. Differences between silk net and GIII net samples include the size of the mesh and the speed of tow. Both are ½-meter open conical nets, used primarily in horizontal 30 minute drags above the depth of 16 meters. However, in the cruise 5 series there are 27 oblique 30-minute tows, from depths of 100, 200, and 250 meters to the surface. Samples from stations bracketed by dashed lines were used as individual transects to compare relative abundance of species with respect to neritic and oceanic zones. To supplement the offshore data we examined about 250 coastal and estuarine samples representing the northern half of the Gulf in all seasons of the year. Despite obvious limitations in sampling distribution in both space and time the qualitative results are consistent between sample series and with what is known of these species from other studies. We therefore consider them to be representative of prevailing conditions, although not with respect to seasonal variation.

Each sample was examined thoroughly for species content. Random subsamples of two to three hundred calanoids were used to estimate percentage composition for each tow. On comparing a species' frequency with relative abundance for the four sets of tows mentioned above, we found that both values varied in a similar fashion between stations. Thus we consider concordant variation of frequency values in a group of samples as qualitative evidence of variation in relative abundance with respect to space. For practical purposes we have combined data from the two types of nets, wherever they were obviously similar.

The second slide summarizes environmental conditions in the Gulf. Values for salinity and temperature in degrees centigrade are mean annual extremes and the heavier lines in the lower map are isohyets expressing mean annual rainfall in inches. As you can see, the study area offers several interesting advantages for examining plankton distribution. The hydrographic regime of surface and near surface depths appears to be fairly straightforward. There is only limited contact with adjacent water bodies and the currents between them are essentially unidirectional. Circulation in the western Gulf appears to be composed of weak eddies. Prevailing winds are from the southeast in warm months and from the northeast to northwest in cold months. Along the coast there is extensive geographical variation in climatic conditions and river outflow. With the exception of coastal waters, especially along the northern periphery, and a shallow variable band of mixoeuhaline water extending offshore between the Mississippi Delta and Florida, surface waters are characterized throughout the year by temperatures exceeding 20° C and salinities above 36‰.

Analysis of the collections indicates that 1) species tend to be distributed independently of others, 2) as a group they constitute a gradually changing community arranged along an onshore-offshore gradient and 3) along the gradient, indications of more distinctive faunal changes permit subdivision of the fauna into zonal categories. These distributional patterns appear to reflect the influence of at least three sets of environmental factors: 1) response to temperature gradients in the classic biogeographical sense; 2) response to local environmental gradients arranged on an onshore-offshore axis; 3) response to local environmental gradients arranged on a vertical axis. Complications arising from displacement by water transport constitutes special problems which may not be considered with the plankton collections now available.

Biogeographically, the majority of Gulf species are warm water circumglobal forms. Several neritic species show strong temperate North Atlantic affinities as well as varying degrees of adaptability to tropical conditions. Examples include _Centropages hamatus_, _Acartia tonsa_, _Pseudodiaptomus coronatus_, _Labidocera aestiva_ and _Paracalanus crassirostris_. They are dominant in coastal and estuarine waters north of the 28° parallel where monthly mean temperatures range from summer highs above 30° C to winter lows approaching 10° C. Elsewhere along the Gulf coast, where monthly mean surface temperatures normally exceed 18° C throughout the year these species diminish in numerical importance, some to the extent of being virtually absent.

Indications of faunal response to local horizontal gradients has been observed in our material by several methods. Side by side comparison of records plotted on charts provides evidence of five horizontal groupings.

An estuarine facies can be seen along the northern Gulf coast consisting of species such as Acartia tonsa, Paracalanus crassirostris, Tortanus discaudatus and Pseudodiaptomus coronatus. They occur in greatest abundance in mesohaline and polyhaline waters of estuaries, large and small inlets and contiguous coastal waters. Some are also abundant in metahaline lagoons such as the Laguna Madre. The apparent absence of the grouping in the southern half of the Gulf is probably the result of inadequate sampling.

The second grouping referred to as the coastal-neritic facies is found chiefly in mixohaline to euhaline waters along the inshore half of the neritic province. Species include Centropages furcatus, Labidocera aestiva and Temora turbinata. Their penetration into estuaries is usually limited to the seaward-most portions. On the other hand, estuarine species appear to extend more deeply into the coastal-neritic environment.

Other predominantly neritic species such as *Eucalanus pileatus*, *Paracalanus parvus* and *Temora stylifera* appear to range equally well over the entire neritic province and extend into slope waters. They appear typically in small numbers when found beyond this range. Their penetration into estuaries is perhaps slightly more limited than that of coastal-neritic species despite evidence of similar euryhaline qualities.

The next grouping is referred to as oceanic-slope species and includes such forms as *Clausocalanus furcatus*, *Undinula vulgaris* and *Paracalanus aculeatus*. These ubiquitous species dominate surface waters throughout the oceanic province and also range successfully in the offshore half of the neritic province. They can apparently withstand some fresh water dilution as they have been taken in mixoeuhaline waters on a number of occasions.

The fifth horizontal grouping, the oceanic facies, contains species which appear to be confined to euhaline waters of the oceanic province. Representatives include *Centropages violaceus*, *Paracalanus nudus* and *Pontellina plumata*.

These distributional groupings can be compared visually in the next slide, which illustrates an example of each type. The maps represent the combined records available for each species used as an example. Frequencies of the species at each station are shown as one of three index levels as per the legend.

Also appearing on this illustration is a sixth grouping, oceanic-subsurface, species, illustrated by Pleuromamma gracilis and also containing Lucicutia flavicornis and Calanus gracilis.

Recognition of the subsurface group was made by considering the occurrence of species with relation to such factors as time and depth of tow. In this phase of the study we also examined occurrence with respect to coastal, outer neritic, slope and oceanic zones, type of collecting gear, temperature and salinity. The results of this analysis for the same forms used to illustrate species groupings is shown on the next slide. The data are plotted as histograms, percentage occurrence above the baseline being the ratio of the number of records to the total number of samples. Symbols under the heading -offshore range- are as follows: N1 refers to stations between the coast and the 50 fathom isobath, N2 to stations between the 50 and 100 fathom isobaths, S1 to stations between the 100 and 1000 fathom isobaths and O to stations beyond the 1000 fathom isobath.

Comparisons with temperature and quadrant of the Gulf have been omitted as there are no clearcut indications that the distribution varies within the range.

Selection of 35.5‰ as the dividing point in the salinity range is based on the fact that salinities at or below this level in the Gulf are indicative of recent admixture of fresh or low salinity water. However the converse does not hold for salinities above this level. The small number of data prevented use of a greater number of intervals. The number of tows for each set of variables are not equal since data from oblique tows were omitted and salinities were unavailable for several other tows. Distribution with respect to offshore range and salinity is in substantial agreement with the results obtained from mapping of the records. The greater frequency of Pleuromamma gracilis in night samples and in the oblique tows is indicative of its subsurface distribution and its records shown in the previous slide indicate distinct oceanic range.

In the next slide we can compare the relative abundance of several species including our previous examples with respect to oceanic and neritic localities. The samples of each transect are relatively synoptic and obtained by the same collecting gear. In addition to the depth profile temperatures and salinity, values at each station are shown for purpose of reference. The species are listed in order of their relative distributional overlap. These data strengthen results already mentioned as well as the conclusions drawn from the next and last slide.

To consider relative distributional overlap between pairs of species we made use of a measure of co-occurrence often employed in studies of plant distribution and referred to as the coefficient of the community. This method was recently used with considerable success by Whittaker and Fairbanks in analyzing distributional patterns of fresh water copepods in a group of lakes and ponds. Data from the GIII net and silk net were analyzed separately because of differences in their sampling qualities. The arrangement of the species obtained by this analysis is presented under each matrix. The brackets refer to the groupings determined by mapping records and by estimates of the occurrence as related to several environmental factors. The minor differences between the two matrices can be largely attributed to different collecting characteristics of the two nets.

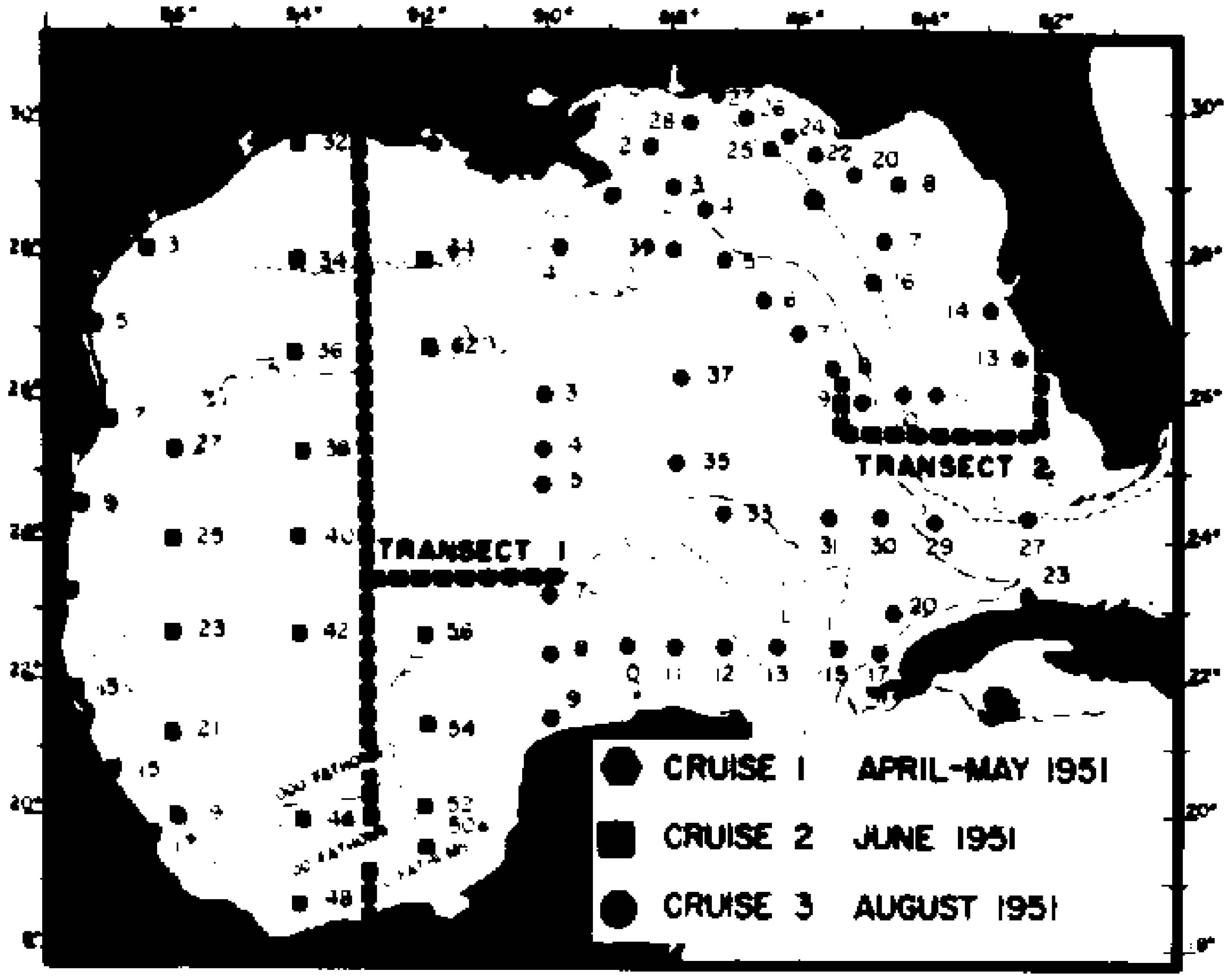
Omitting oceanic subsurface species the trend in each triangle is for co-occurrence values to decrease more or less uniformly in the direction away from the diagonal. This implies that the species are responding primarily to one environmental gradient. From our knowledge of distributional records of these species it is apparent that the undirectional gradient lies along an onshore-offshore axis. Oceanic subsurface species are considered as evidence of another environmental gradient extending in a vertical direction.

It is important to note the fact that the collections used in each triangle were made in different years. In light of the essentially similar results, this strengthens the impression that the results of this study reflect actual conditions rather than sampling artifacts.

CONCLUSION

Spatial distribution of Calanoida in the Gulf of Mexico apparently represents the summation of two sets of related forces. It is partly biogeographical in that the present geographical range is a momentary culmination of a species' historical distribution and its ability to adapt to change. It is also environmental since in marine waters within its geographical range, the species occurs discontinuously and in patterns that indicate response to horizontal and vertical gradients. To reveal those principles underlying plankton distribution increased attention in a variety of regions must be given to (1) detailed analysis of plankton communities in time and space, (2) the environmental needs of key species and (3) the extent of, as well as means by which communities maintain physical integrity within an environment in perpetual flux.

CRUISES 1,2,3



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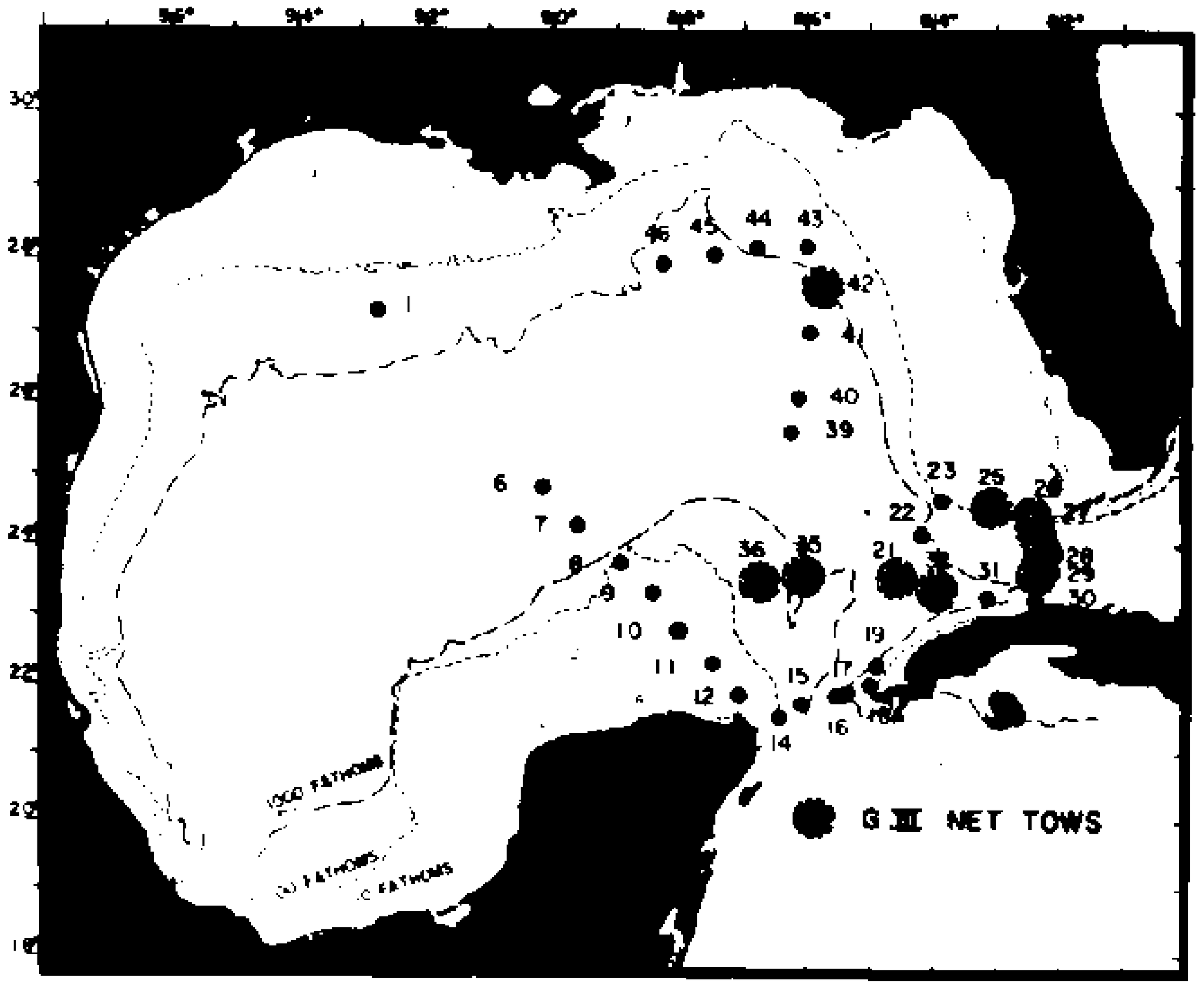

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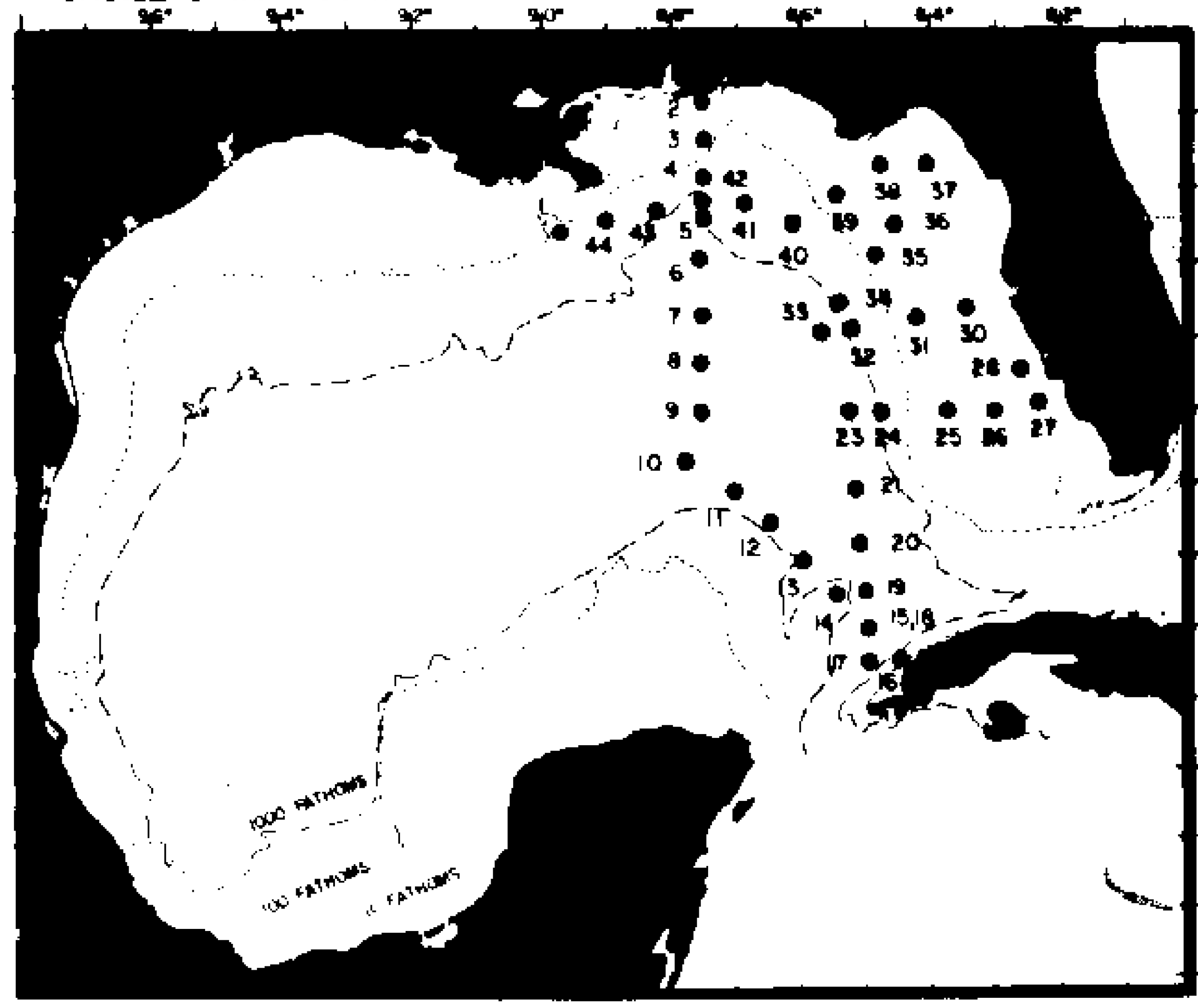

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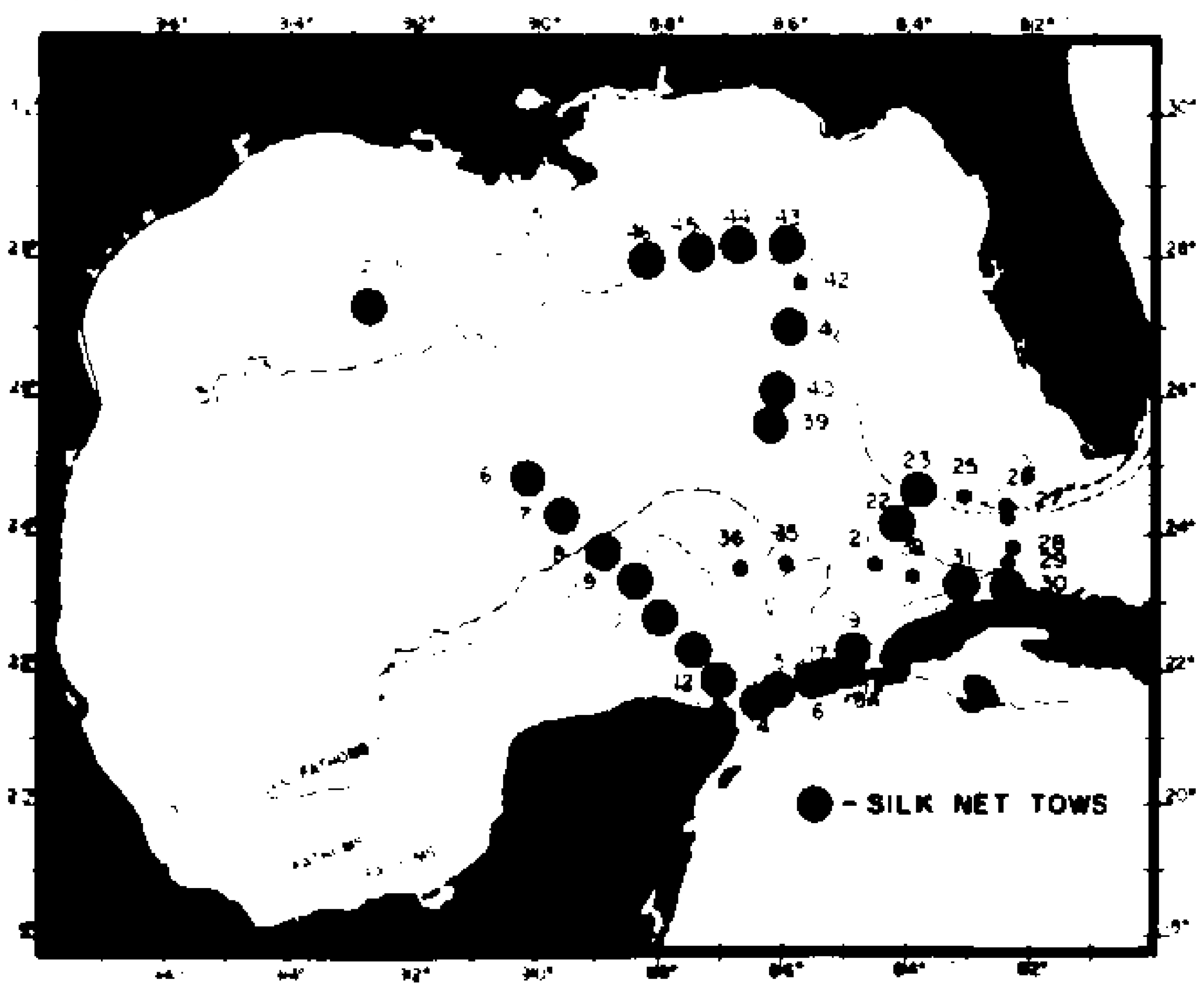

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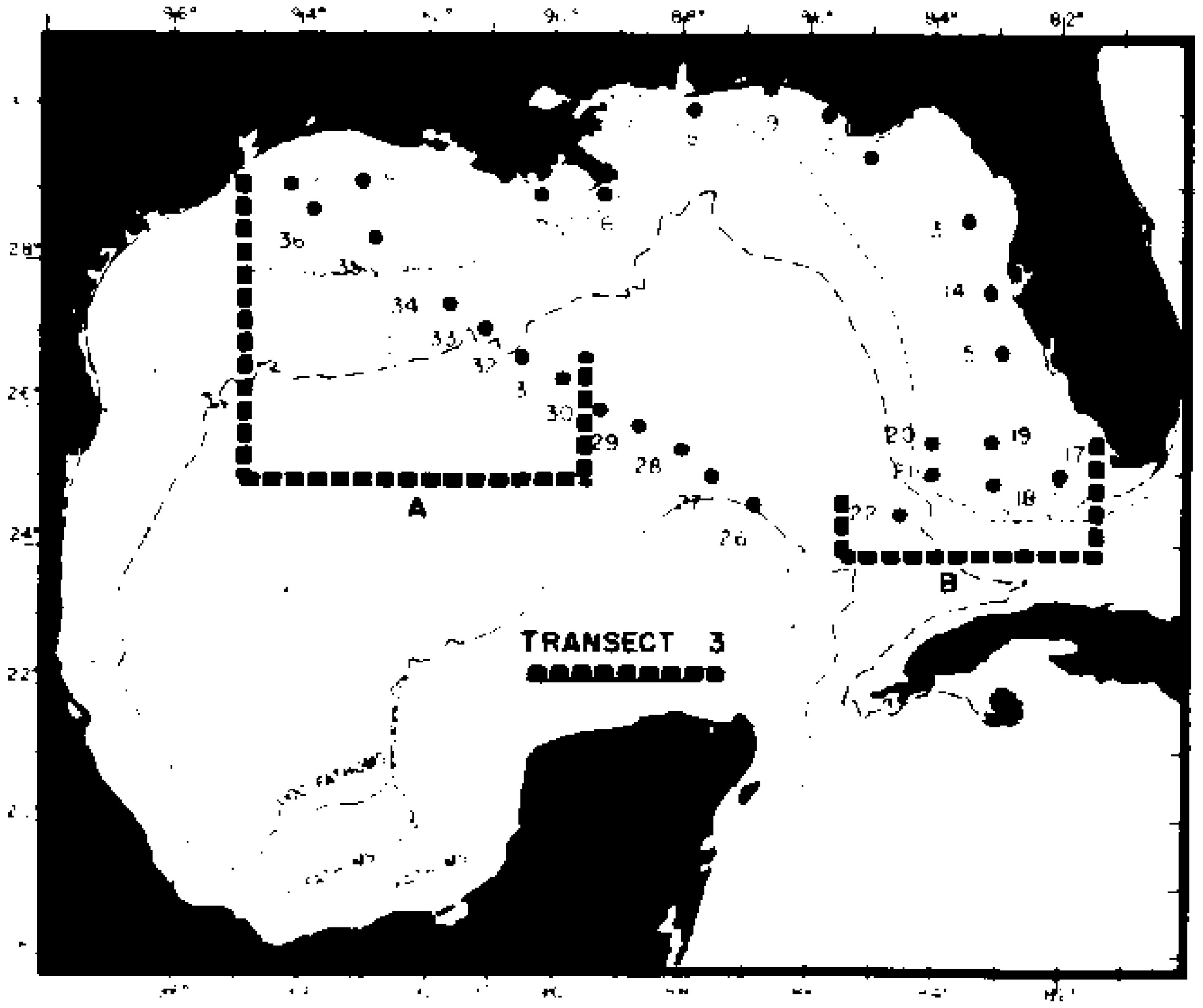

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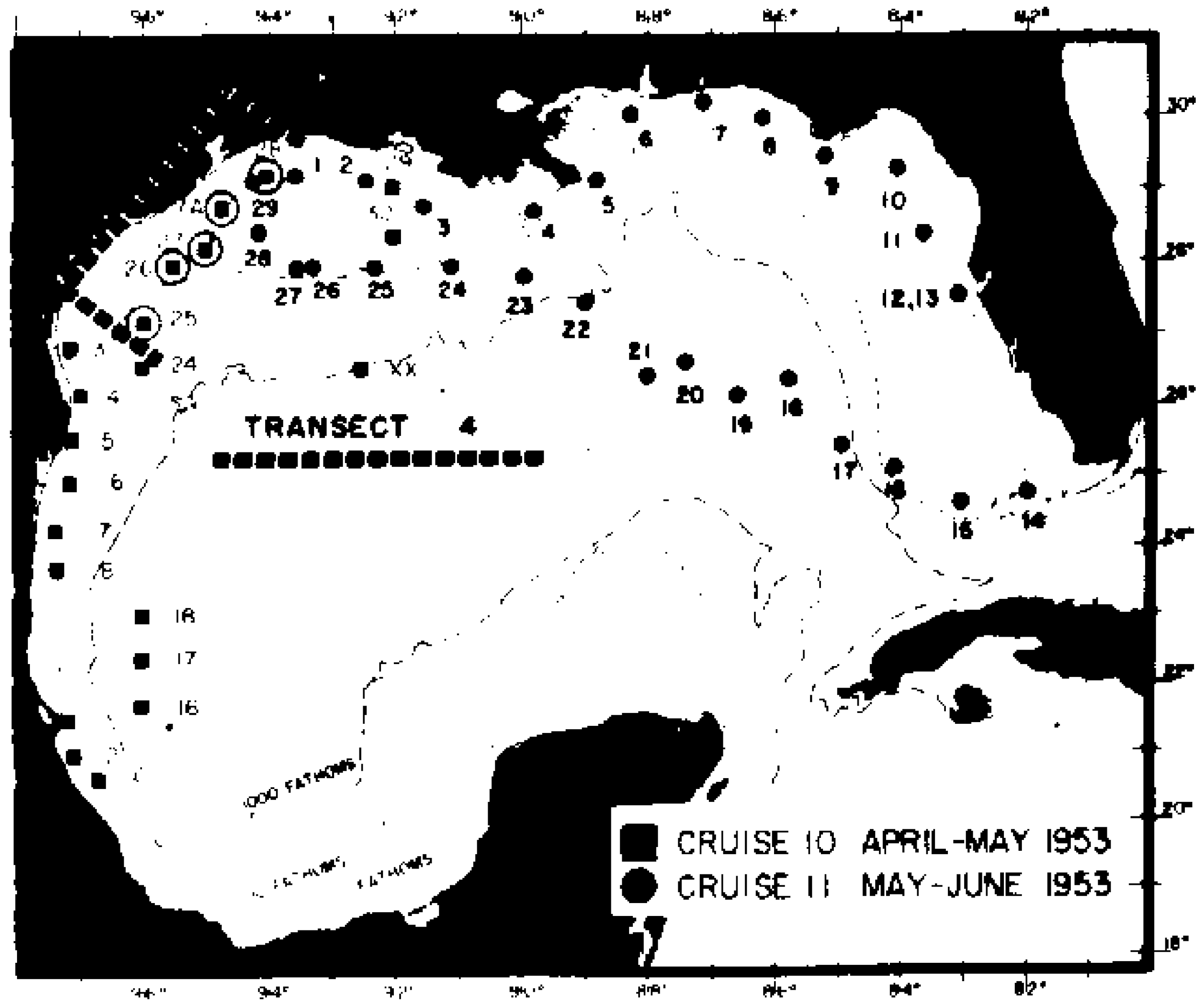
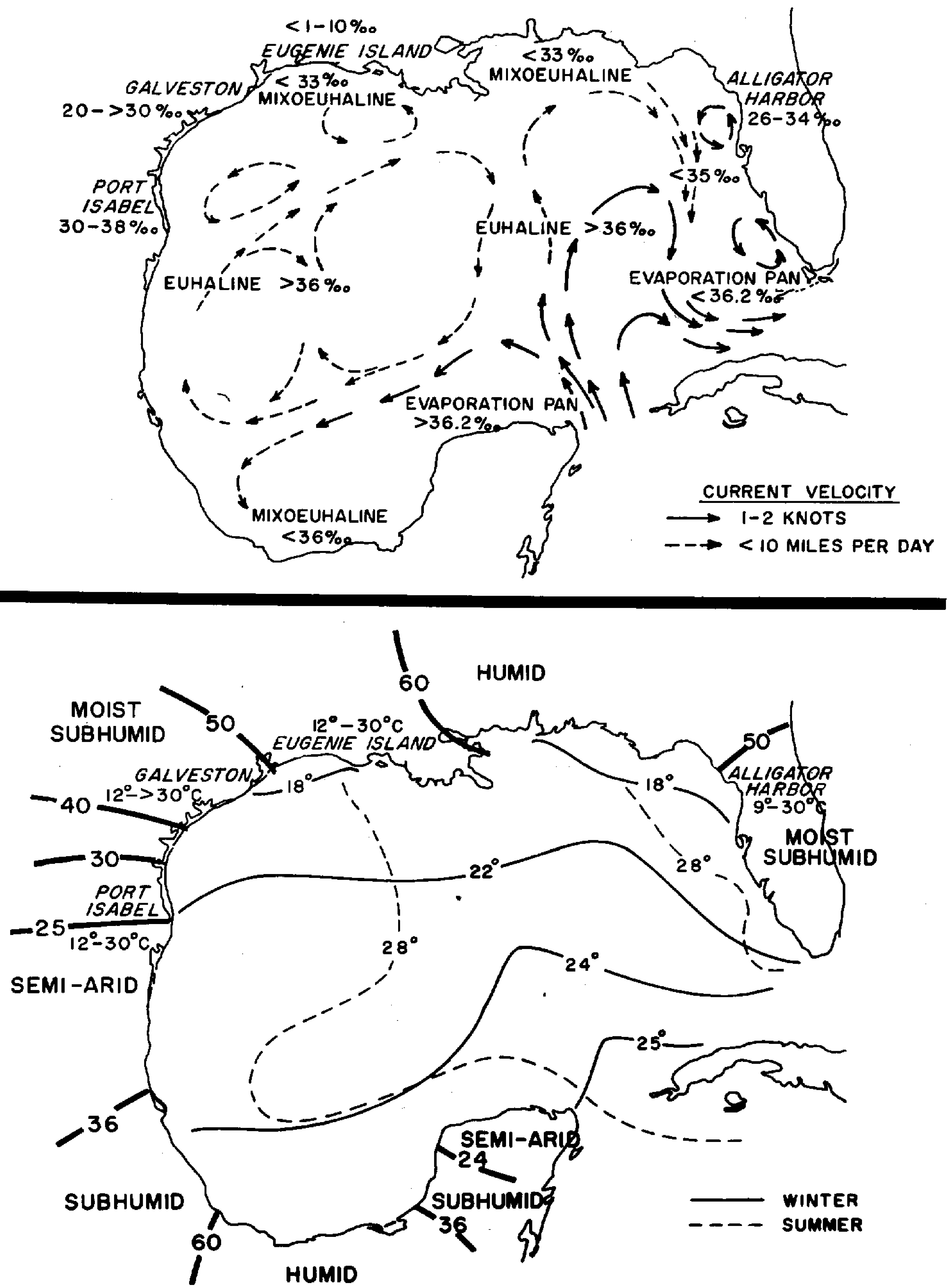


PLANKTON TOWS - ½M & 1M SILK NETS (No.10 MESH)

PLANKTON TOWS - G III NET (No.1 MESH)

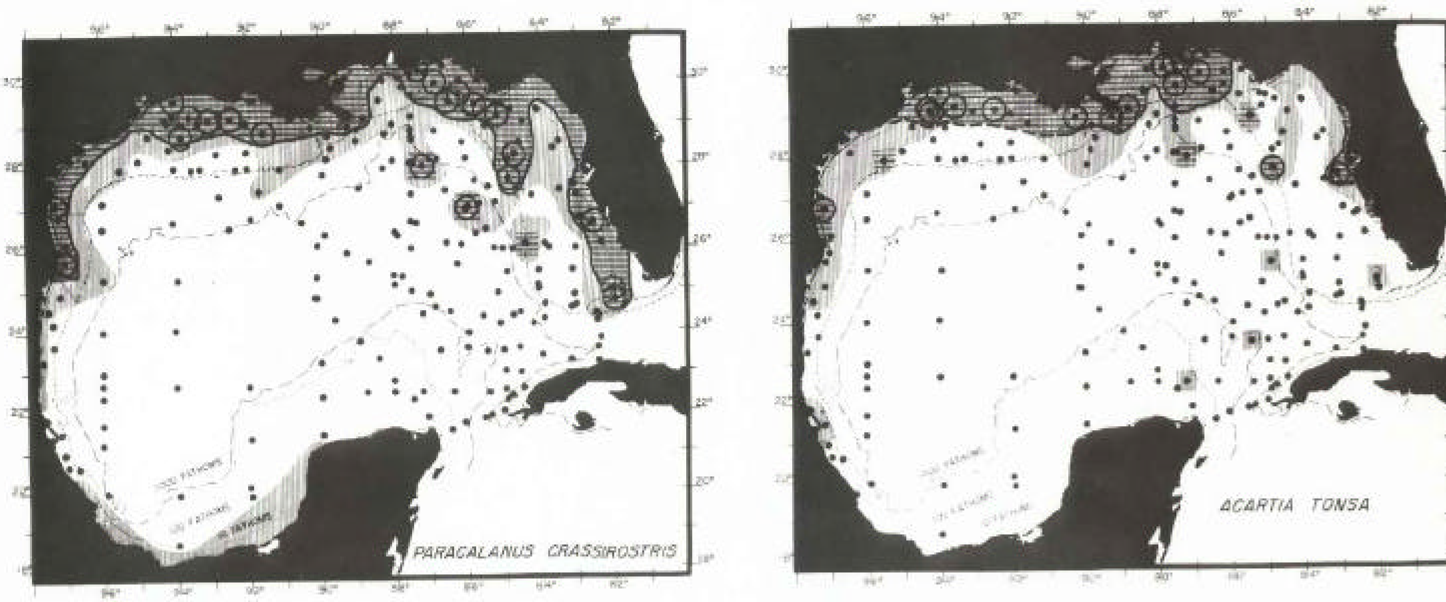
A

B



PREVAILING SURFACE SALINITIES, CURRENTS, CLIMATE, AND MEAN ANNUAL SURFACE TEMPERATURE.

ESTUARINE SPECIES

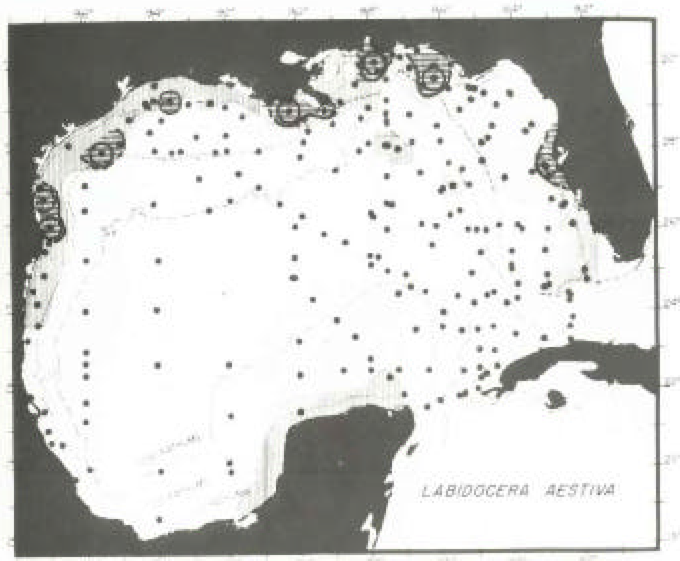


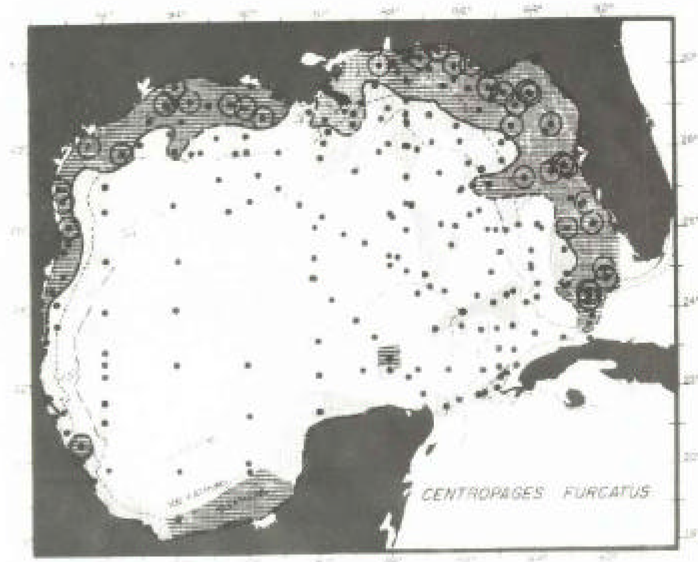
FREQUENCY (PERCENTAGE) IN TOWS:

||||| = PRESENT, <1% ▦ = 1–5% ○ = >5%

C

COASTAL—NERITIC SPECIES



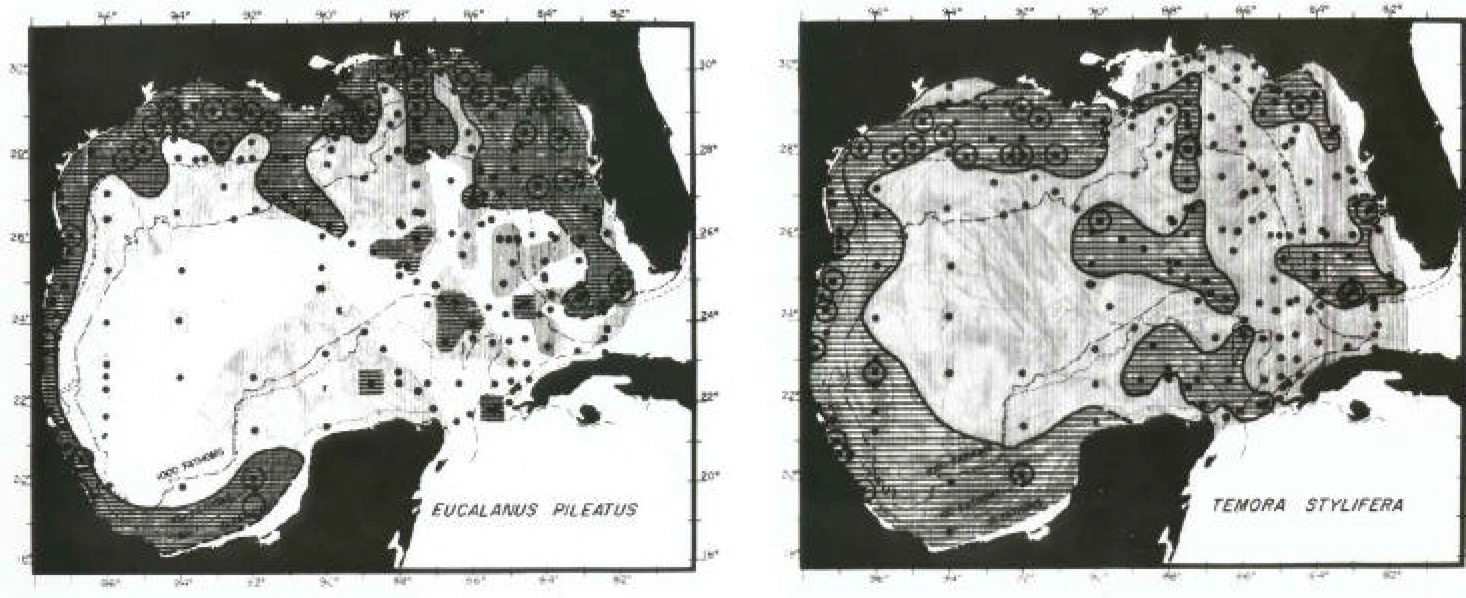


FREQUENCY (PERCENTAGE) IN TOWS:

= PRESENT, <1%   = 1–5%   ○ = >5%

D

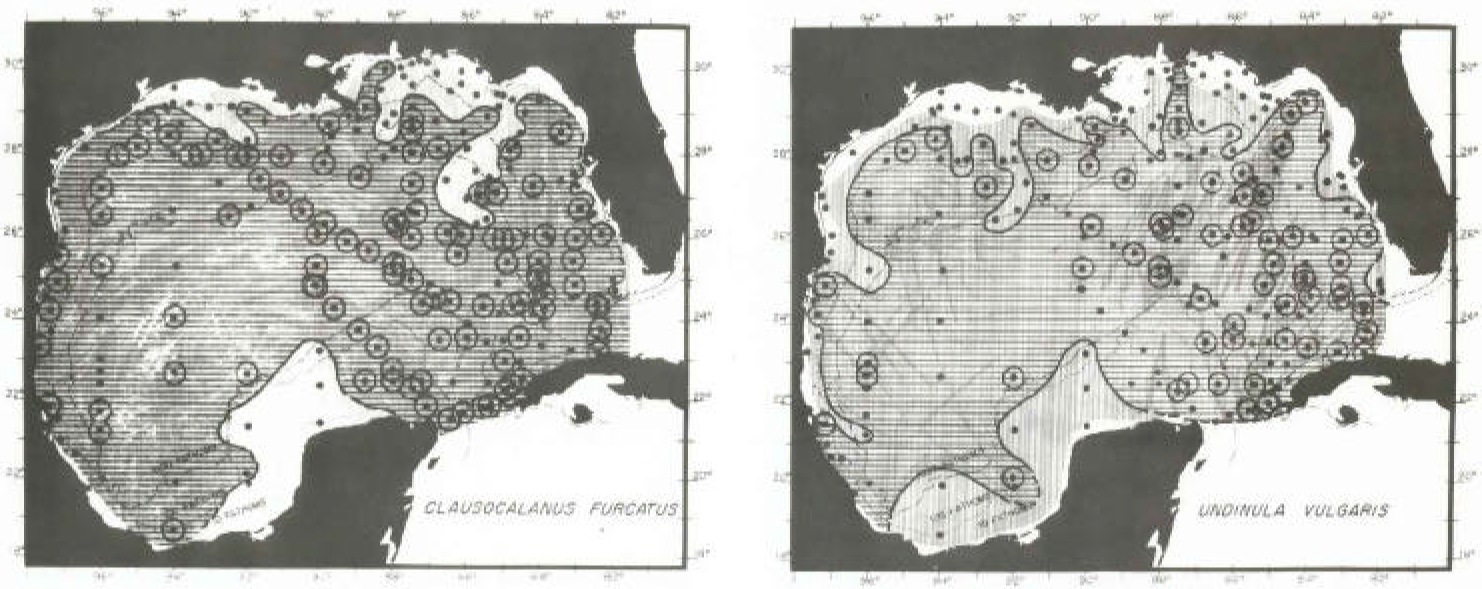
NERITIC—SLOPE SPECIES



FREQUENCY (PERCENTAGE) IN TOWS:

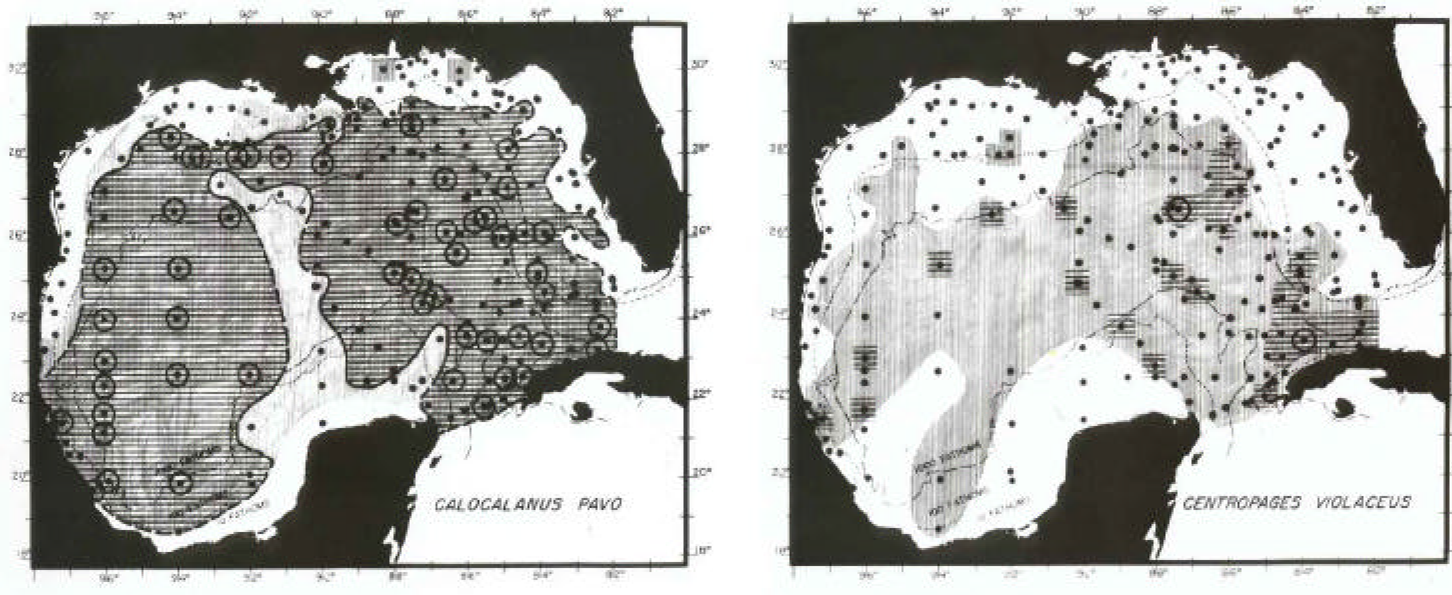
▥ = PRESENT, <1%   ▦ = 1–5%   ◯ = >5%

OCEANIC—OUTER NERITIC SPECIES



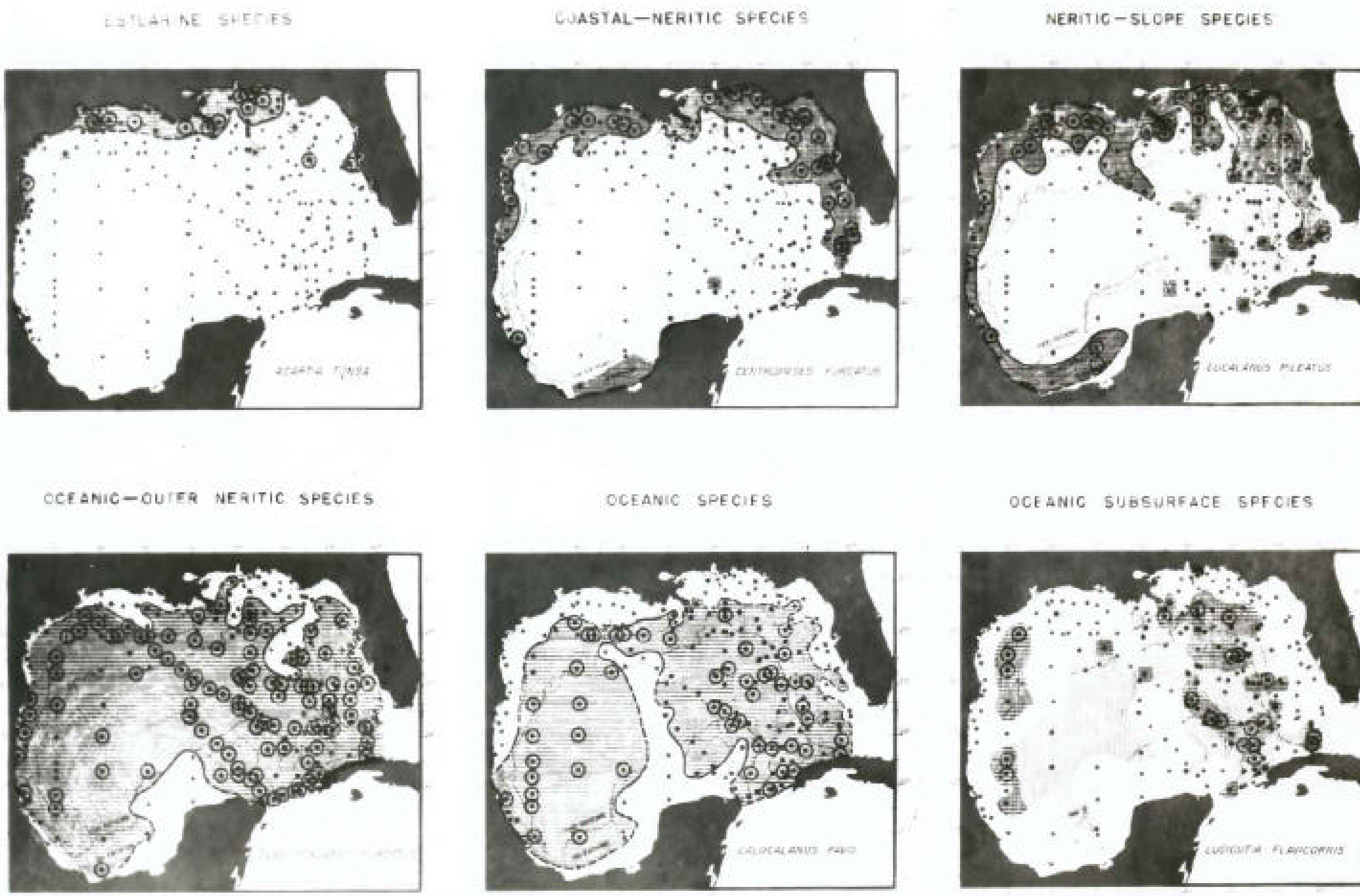
FREQUENCY (PERCENTAGE) IN TOWS:
= PRESENT, <1% = 1–5% ○ = >5%

OCEANIC SPECIES



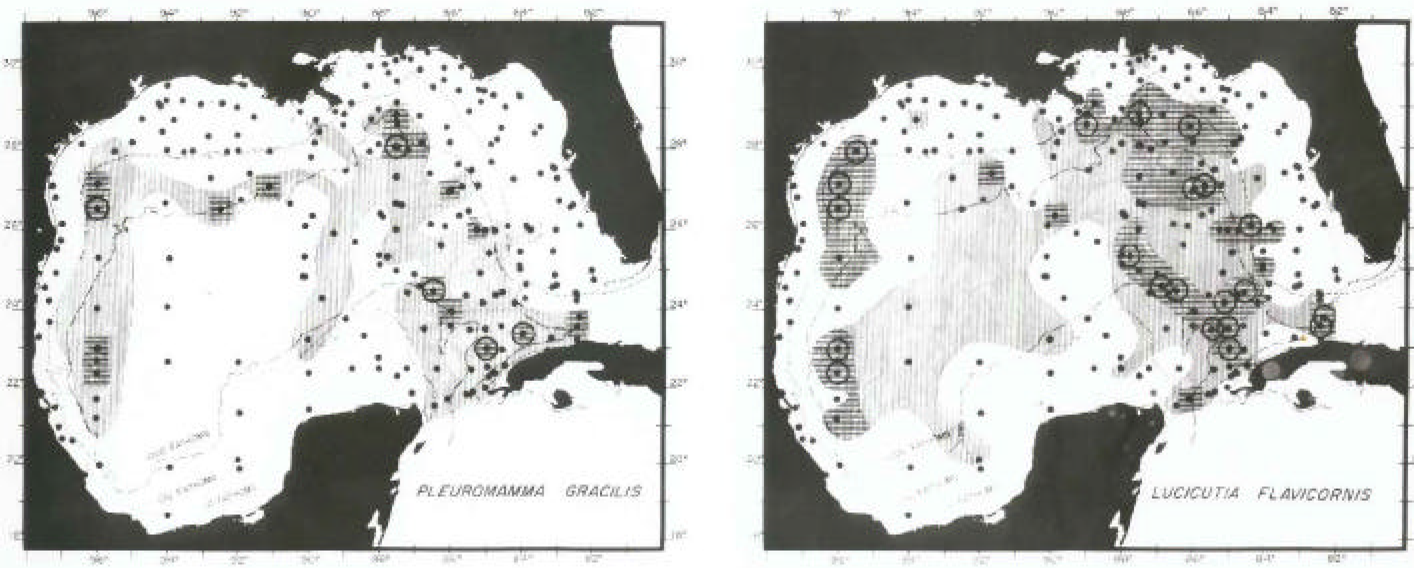
FREQUENCY (PERCENTAGE) IN TOWS:

= PRESENT, <1%   = 1–5%   ○ = >5%



FREQUENCY (PERCENTAGE) IN TOWS:
= PRESENT, <1%   = 1–5%   O = >5%

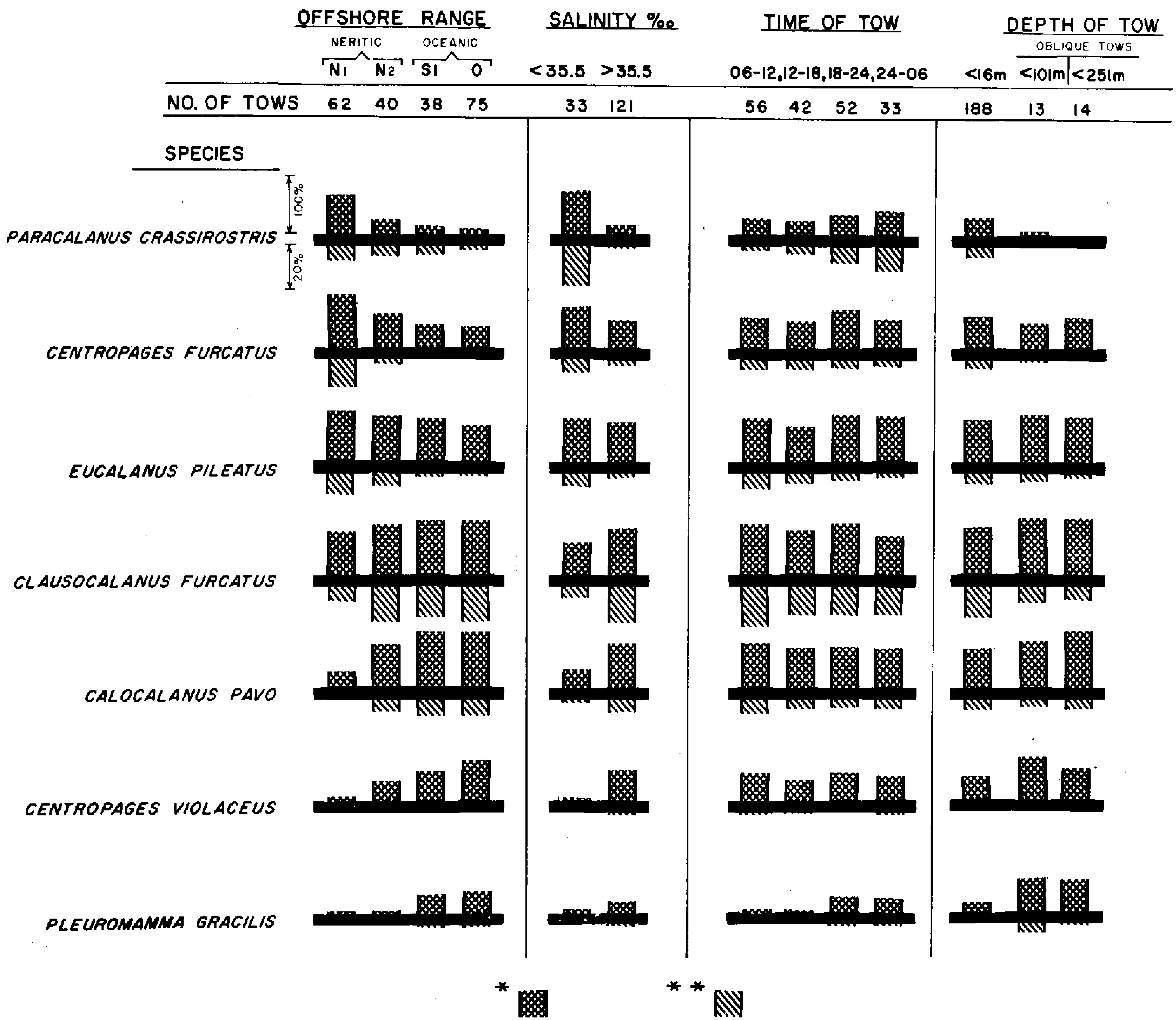
OCEANIC SUBSURFACE SPECIES



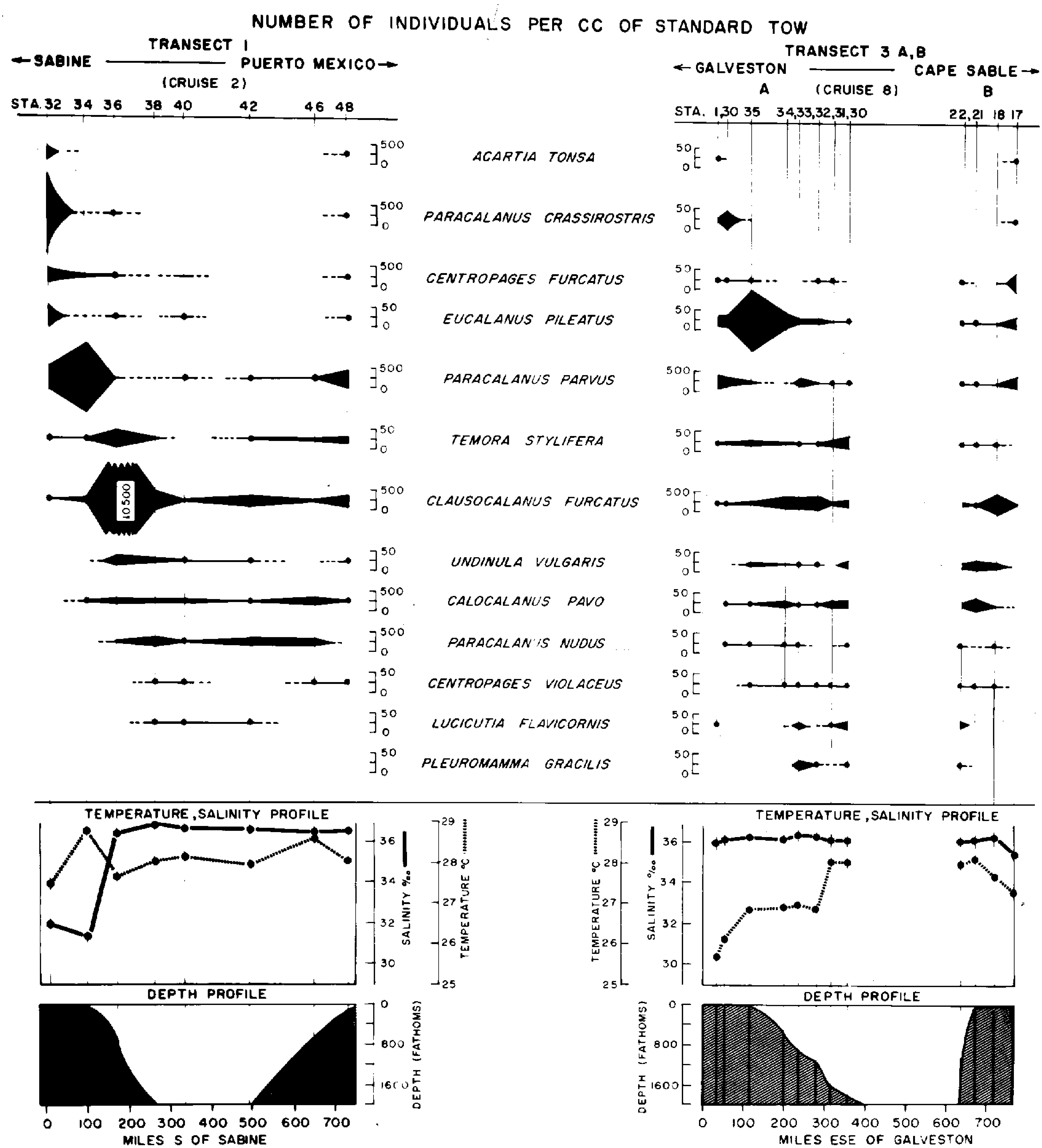
FREQUENCY (PERCENTAGE) IN TOWS:

||||| = PRESENT, <1% ▦ = 1–5% ◯ = >5%

PERCENTAGE OCCURRENCE (ABOVE)* AND MEAN PERCENTAGE FREQUENCY (BELOW)** WITH RESPECT TO SAMPLING VARIABLES (SILK NET AND G III NET DATA COMBINED).



K



NUMBER OF INDIVIDUALS PER CC OF STANDARD TOW
TRANSECT I
← SABINE — PUERTO MEXICO →
(CRUISE 2)
STA. 32 34 36 38 40 42 46 48
TRANSECT 3 A,B
← GALVESTON — CAPE SABLE →
A
(CRUISE 8)
B
STA. 1,30 35 34,33,32,31,30 22,21 18 17
10500
ACARTIA TONSA
PARACALANUS CRASSIROSTRIS
CENTROPAGES FURCATUS
EUCALANUS PILEATUS
PARACALANUS PARVUS
TEMORA STYLIFERA
CLAUSOCALANUS FURCATUS
UNDINULA VULGARIS
CALOCALANUS PAVO
PARACALAN'S NUDUS
CENTROPAGES VIOLACEUS
LUCICUTIA FLAVICORNIS
PLEUROMAMMA GRACILIS
TEMPERATURE, SALINITY PROFILE
SALINITY ‰
TEMPERATURE °C
DEPTH PROFILE
DEPTH (FATHOMS)
MILES S OF SABINE
MILES ESE OF GALVESTON

G-III Net Tows (130)

	S	R	O	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
A	7	12	11	6	9	14	16	18	19	21	20	23	25	29	30	30	37	39	
B	6	12	10	3	3	10	10	9	16	20	21	22	25	32	36	29	37		
C	15	28	24	19	24	26	41	42	50	57	57	39	64	72	67	60			
D	13	35	33	29	37	32	49	52	57	60	63	69	67	69	66				
E	18	36	32	26	36	37	17	57	61	69	67	72	75	82					
F	27	42	21	30	38	25	59	51	68	76	76	81	82						
G	28	36	41	31	50	45	73	70	81	86	86	64							
H	30	49	43	32	53	47	75	73	84	87	89								
I	43	49	39	27	51	47	74	73	93	85									
J	32	52	45	33	54	47	76	75	79										
K	31	47	48	33	58	46	81	75											
L	38	62	58	40	59	51	79												
M	36	43	54	42	60	54													
N	44	56	55	47	51														
O	43	50	55	36															
P	44	48	49																
O	63	73																	
R	58																		
S																			

Silk Net Tows (99)

A	B	C	F	D	E	G	H	I	K	M	J	N	P	O	L	Q	R	S	
	55	37	18	11	21	11	5	8	10	8	3	4	3	2	2	3	2	3	A
		58	32	22	36	25	7	17	20	16	12	8	7	3	8	8	4	5	B
			44	45	49	36	26	30	28	24	28	26	20	13	17	15	18	19	C
				53	57	57	51	45	55	49	48	40	49	30	23	12	23	17	F
					53	56	49	60	48	48	57	22	46	35	36	27	37	26	D
						75	62	67	66	60	49	40	45	35	25	23	24	16	E
							69	70	76	70	61	47	49	42	29	24	28	16	G
								75	83	80	65	66	57	50	32	28	31	19	H
									74	69	66	58	55	45	34	29	31	21	I
										88	56	64	55	48	18	24	29	17	K
											54	66	56	50	35	25	32	19	M
												57	95	40	45	33	41	17	J
													67	55	36	32	37	27	N
														56	43	31	45	31	P
															44	35	38	25	O
																23	49	35	L
																	38	37	Q
																		54	R
																			S

G-III Spp.

A = Acartia tonsa
B = Paracalanus crassirostris
C = Centropages furcatus
D = Temora turbinata
E = Paracalanus parvus
F = Eucalanus pileatus
G = Temora stylifera
H = Clausocalanus furcatus
I = Paracalanus aculeatus
J = Calanus minor
K = Undinula vulgaris
L = Euchaeta marina
M = Calocalanus pavo
N = Calocalanus gracilis
O = Centropages violaceus
P = Paracalanus nudus
O = Calanus gracilis
R = Lucicutia flavicornis
S = Pleuromamma gracilis

ESTUARINE SPECIES

COASTAL-NERITIC SPECIES

NERITIC-SLOPE SPECIES

OCEANIC-OUTER NERITIC SPECIES

OCEANIC SPECIES

OCEANIC SUBSURFACE SPECIES

Silk Net Spp.

A = Acartia tonsa
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M = Calocalanus pavo
J = Calanus minor
N = Calocalanus gracilis
P = Paracalanus nudus
O = Centropages violaceus
L = Euchaeta marina
Q = Calanus gracilis
R = Lucicutia flavicornis
S = Pleuromamma gracilis

Matrix (Kulczyński triangle) of relative distributional overlapping of species. Percentage co-occurrence (PC) values (Whittaker and Fairbanks, 1958) of paired species derived from percentage of samples containing both species (c) among samples containing one (a), the other (b) or both (c):

$$PC = \frac{c}{a + b - c}$$

Sequence obtained by arranging species so as to bring high index values, indicating greater overlap in distribution, toward diagonal of matrix. Grouping of species based on zones of shifting, lowered index values separating clusters of comparatively similar higher values. Reduced for purpose of simplification from original matrices based on the 40 most frequently occurring species in the collections: minimum species in G-III net series, 32 records in 130 tows, for silk net series 15 records in 99 tows.